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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ March 8, 1918

THE MELON FLY

By

E. A. BACK, Entomologist
and C. E. PEMBERTON, Assistant Entomologist
Mediterranean and Other Fruit Fly Investigations

CONTENTS

	Page		Page
What the Melon Fly is Like	3	Interesting Facts Concerning the Adult Fly	22
Origin and Distribution	4	Why the Melon Fly is a Serious Pest	24
Establishment and Spread in Hawaii	4	Control Measures	25
Methods of Spread	7	Measures Taken to Keep Fruit Flies of Hawaii from Gaining a Foothold in Continental United States	29
Economic Importance	7		
Nature of Injury Caused by the Melon Fly	8	Summary	30
Food or Host Plants	16		

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THE MELON FLY is a truck-crop pest that in the course of international commerce has been spread from its native home in the Indo-Malayan region to the Hawaiian Islands, and has become so thoroughly established that it can not be eradicated. Owing to its destructive work, such fruits as muskmelons, watermelons, pumpkins, squashes, cucumbers, vegetable marrows, and tomatoes can not be grown to-day in many parts of the Hawaiian Islands unless the plants are screened. Cantaloupes and watermelons, instead of being common and cheap delicacies, as in former years, are now a luxury even for the wealthy; and cantaloupes, formerly grown in quantities about Honolulu, are now imported from California. Owing to the danger of introducing the melon fly into countries where it does not now exist, quarantines prohibit the export of Hawaiian-grown eggplant, bell peppers, and tomatoes, thus shutting off an income formerly enjoyed by the small farmer. In short, it is not possible to exaggerate the seriousness of this insect under Hawaiian coastal conditions.

The problem, however, is not entirely a local one to be fought out by the people of Hawaii. Should the melon fly once break through the Federal quarantine barriers and become established on the mainland of the United States, it will exact a large annual toll of the truck crops of the South. It is important, therefore, that truck growers learn something about this pest, so difficult of control, in order that they may become actively interested in keeping it out.

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CONTENTS.

	Page.		Page.
What the melon fly is like	3	Interesting facts concerning the adult fly	22
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Establishment and spread in Hawaii	4	Control measures	25
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THE MELON FLY is a serious pest that never should have gained access to the Hawaiian Islands. Its establishment in Hawaii came naturally enough, as in the case of many of our worst insect enemies, along with the development of unrestricted modern commerce, and owing to the lack, in earlier days, of a knowledge of pests in other lands likely to be introduced into ours, or of any quickened public opinion which, at last thoroughly alive to the great financial losses that may be averted, is to-day heartily supporting Federal quarantines directed against just such pests as the melon fly.

The melon fly is now established thoroughly throughout the coastal regions of the Hawaiian Islands and never will be eradicated. It attacks many vegetables that otherwise could be grown readily by the poorer people, who are least able to purchase them. Melons, pumpkins, squashes, cucumbers, and tomatoes, and some

[1] *Bactrocera cucurbitae* Coq.; order Diptera, family Trypetidae.

For a more extended account of the melon fly see Back, E. A., and Pemberton, C. E. The melon fly in Hawaii. U. S. Dept. Agr. Bul. 491. 64 p., 24 pl., 10 fig. 1917. This may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 25 cents.

Note.—The manuscript of this paper was prepared for publication as a Farmers' Bulletin, but owing to the fact that it deals with an insect which has not yet been introduced into the continental United States it was considered more appropriate to issue it in the series of Department Bulletins.

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other vegetables to-day can not be grown in many parts of the islands except with great effort; they must be imported from across the sea, as a result of melon-fly attack.

The melon fly is capable of living and causing damage throughout the warmer portions of the mainland United States. As it is

FIG. 1.—Tip of watermelon vine, showing adult melon fly laying eggs in ovary of a flower still in bud, an unaffected male bloom, and withered and drooping growing tip of vine. A female melon fly has deposited eggs in the vine at base of leafstalk, and the young larvæ hatching have nearly severed the vine at this point. (Authors' illustration.)

being intercepted rather frequently by official inspectors at California ports on ships from Hawaii, the importance of cooperation by all in making the quarantine of the Federal Horticultural Board a success in keeping out this very serious pest will be readily appreciated.

WHAT THE MELON FLY IS LIKE.

The melon fly, like other so-called "fruit flies," is similar to the ordinary house fly in some respects; the adult lays small white eggs from which hatch larvæ, or maggots, which when full grown transform into pupæ. Later the adult emerges from the pupa, as the butterfly does from the chryalis, and the cycle of life—adult, egg, larva, pupa—is repeated with each successive generation. Figure 1 shows an adult melon fly about to lay eggs in the bud of a watermelon. Note the relative size of the fly and the bud. The adult female, greatly enlarged, is shown in figure 2. When it is remembered that the adult is from one-fourth to one-third of an inch long, that its body is of a yellowish to a yellowish-brown color,

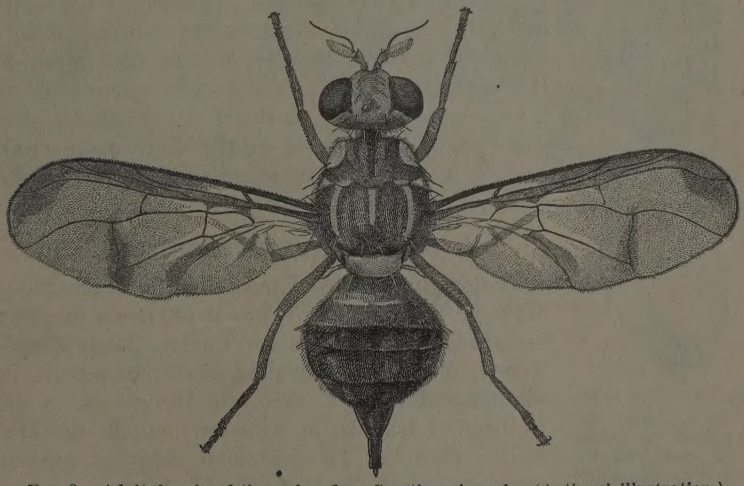

FIG. 2.—Adult female of the melon fly. Greatly enlarged. (Authors' illustration.)

and the markings between the wings, which appear white in the figure, are bright canary yellow in the living insect, and that the wings are banded with dark brown, it will not be difficult to recognize this pest.

The female fly drills small, pinhole-like openings in the skin of vegetables with the sharp tip of her body, called the ovipositor. Through these punctures she lays her white eggs, which are about one twenty-fifth of an inch long. If a small squash flower be cut open after the female fly has laid her eggs, a small cavity containing the eggs, such as is illustrated by figure 3, is shown. The larvæ, or maggots, that hatch from the eggs feed in various parts of the host plant. They have two black hooklike processes in the head that serve as jaws in aiding them to break up their food and to force their way

through the plant tissues. But as the larvæ, even when full grown, are only about two-fifths of an inch long, a detailed description of them is of little value. It is enough to know that they differ very little from the ordinary white maggots, of equal size, with which the reader is doubtless familiar. The larvæ when full grown leave the host to transform to the pupa stage just beneath the surface of the soil, or beneath any protecting object. They even may transform to the pupa within the host fruit, but this is a rare occurrence. Figure 4 shows larvæ and pupæ about twice natural size. In figure 6 are shown well-grown larvæ feeding in the root of a young watermelon plant. Figure 5 represents an enlarged larva.

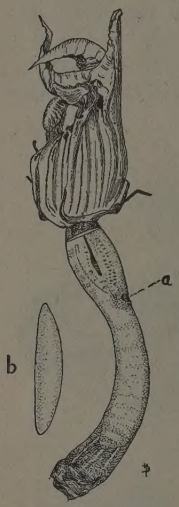

FIG. 3. — The melon fly: *a*, Eggs deposited in cavity in young pumpkin flower; *b*, single egg, much enlarged. (Authors' illustration.)

As the melon fly usually first forces itself upon the attention of the market gardener by the damage it does, it is more important to be able to recognize it by its work than by a mere description of the different stages. The reader, therefore, is directed particularly to the illustrations, for, besides showing types of injury, they make clear that it is in the larva stage that the melon fly causes its greatest damage.

ORIGIN AND DISTRIBUTION.

The original home of the melon fly is the Indo-Malayan region. At present it is known to occur in various parts of India, in Ceylon, Java, Macao, Timor, northern Australia, about Singapore, in southern China at Canton and Hongkong, in the Philippine Islands, in Formosa, and in the Hawaiian Islands. There is some doubt at present about its occurrence at Nagasaki, Japan.

It is believed that the melon fly was introduced into the Hawaiian Islands at Honolulu from Japan or China. It probably arrived in the larva stage in vegetables brought along as food from Japan by Japanese coolies emigrating as steerage passengers to work on the sugar plantations in Hawaii.

ESTABLISHMENT AND SPREAD IN HAWAII.

The melon fly was first observed in Hawaii, so far as records show, by Mr. Byron O. Clark, who, during October to December, 1897, found it almost impossible to grow cucumbers, squashes, melons, and similar vegetables in the Kalihi district of Honolulu and about Pearl City. During August, 1898, the pest already was established at Lau-

pahoehoe, Island of Hawaii. Indications are that the melon fly was introduced as early as 1895.

That the melon fly is an introduced pest is proved by the interesting fact that the gourd calabashes used by the Hawaiian natives during the past century, many of which are preserved in various

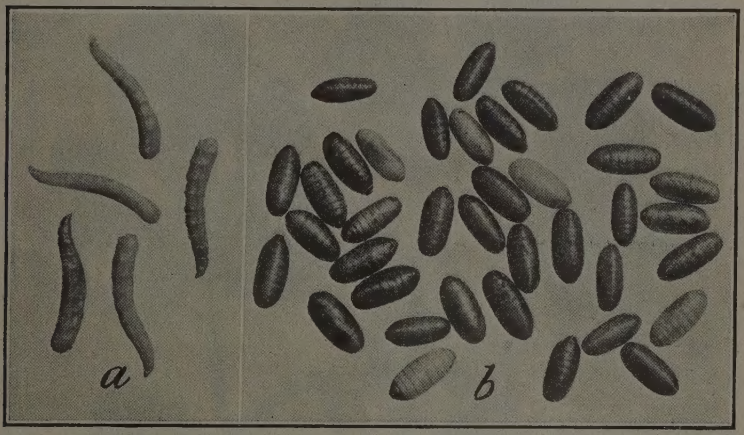

FIG. 4.—Melon fly: *a*, Well-grown larvæ; *b*, puparia. Twice natural size. (Original.)

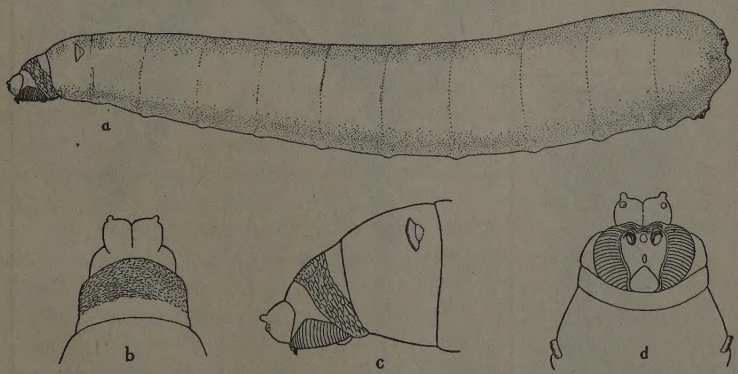

FIG. 5.—The melon fly: Third-instar larva. *a*, Lateral view of entire body; *b*, dorsal view of anterior end; *c*, *d*, lateral and ventral views of same. Much enlarged. (Authors' illustration.)

museums and private collections, are free from evidences of melon-fly attack. Modern utensils largely have superseded calabashes during these later days, but the few that are grown show the surface defects due to the attack of the melon fly.

Although no satisfactory record has been made of the spread of the melon fly to the various islands of Hawaii, it is now a well-

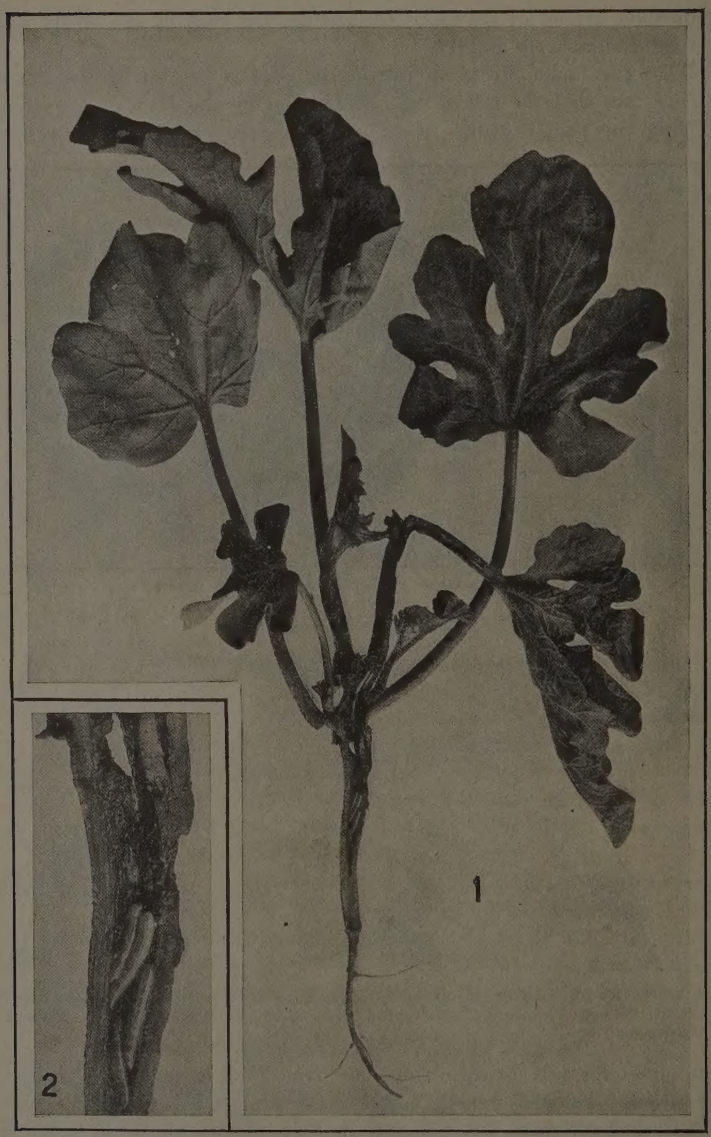

FIG. 6.—*1*, Watermelon seedling destroyed by larvæ of melon fly feeding in taproot, crown, and leaf petioles; *2*, work of larvæ in root, enlarged. (Authors' illustration.)

established and serious pest throughout all the coastal regions. It has been known even to attack cucumbers and squash at altitudes ranging up to 4,000 or 4,500 feet.

METHODS OF SPREAD.

The melon fly probably is carried more often from one locality or country to another in the larva stage than in any other form. Quarantine officials at San Francisco have found living larvæ in host fruits arriving at San Francisco on ships from Honolulu, and records prove that the melon fly in the larva stage is able to bridge the six or seven days required by the slower vessels to cover the 2,000 miles between the Hawaiian Islands and California, since infested fruits have been intercepted and condemned at least once a year since 1912. Host fruits taken on board ships as ship's stores are capable of carrying the melon fly as larvæ, or later as pupæ, in the fruit containers, for voyages occupying a longer time than is required to cross the Pacific Ocean, and thus may become a factor in spreading the pest through vessels plying between almost all countries where climatic conditions are favorable for the establishment of the fly.

The spread from one country to another at a considerable distance probably starts with the fly in the larva stage, but the spread from town to town, or over short distances, as between islands of the Hawaiian group, may occur in the adult or pupa stage. A female fly has been observed to alight on an automobile top and be carried 16 miles from the country into the city of Honolulu. On another occasion an adult was seen flying about an interisland boat en route from Honolulu to Hilo, on the island of Hawaii. This fly was not observed after the boat weighed anchor at the port of Lahaina, on the island of Maui, or 72 miles from Honolulu. These two instances will explain the spread of the pest, in the adult stage, about the islands of Hawaii, even if it could not be transported in the larva stage.

When larvæ form their puparia on bare surfaces, and particularly on a cloth surface, the puparia may adhere sufficiently well to make it possible for them to be transported considerable distances under favorable circumstances. Although no definite instances are known where the melon fly has been spread thus, distribution in this fashion is quite feasible and to be expected.

ECONOMIC IMPORTANCE.

The melon fly is the most important pest of varieties of melons, squashes, and curcurbits in general grown in the Hawaiian Islands, and probably elsewhere. Its persistent attack has caused many persons to abandon the growing of the more susceptible host fruits.

Other fruits can be grown for the most part only under cover and at increased cost. The unrestricted cultivation of fruits and vegetables in Hawaii has been ruined by the melon fly and the Mediterranean fruit fly. Though the latter is probably the more to be feared, many persons regard the melon fly as of greater importance from an Hawaiian standpoint, for it attacks with the greatest persistency such crops as squashes, pumpkins, vegetable marrows, tomatoes, and beans, all of which could furnish under the ideal Hawaiian climatic conditions an abundance of food for the poorer people. Such vegetables as muskmelons, watermelons, pumpkins, squashes, and tomatoes can not be grown to-day in many parts of the islands unless the plants are screened carefully.

FIG. 7.—Older squash vine with abnormal growths due to work of melon-fly larvæ. (Authors' illustration.)

Cantaloupes and watermelons, instead of being common and cheap delicacies, as in former years, are now a luxury for even the wealthy. Cantaloupes, once grown in large quantities about Honolulu, now are imported from California. It is no longer possible to grow pumpkins as stock food on idle land. Quarantines prohibit the export of early shipments of eggplant, bell peppers, and tomatoes, thus shutting off an income formerly enjoyed by the small farmer. The loss to market gardeners in Hawaii as a result of melon-fly attack has been placed conservatively at three-fourths of a million dollars annually. It is not possible to exaggerate the importance of the melon fly as a serious pest under Hawaiian coastal conditions.

NATURE OF INJURY CAUSED BY THE MELON FLY.

The melon fly does not confine its attack to the fruits of its host or food plants. It may attack the young seedling, the flower, the root, the stem, or the fruit.

INJURY TO SEEDLING PLANTS.

The melon fly attacks with severity the young succulent seedling plants of watermelon and cantaloupe. The female fly lays her eggs in

the crown of the plant, and the larvæ, on hatching, feed there first. They later burrow down into the taproot and upward into the petioles of the leaves, and even into any young runners that are forming. The capacity of the melon fly for injuring a watermelon seedling is shown in figure 6 (p. 6). The enlarged figure of the root shows four full-grown larvæ eating their way into the root. In the figure of the seedling the larvæ have almost severed the leaf to the left, and have tunneled completely through one of the petioles and so destroyed it that the weight of the leaf has caused its stem to break over. Injury to a seedling runner is shown in figure 8. In certain places in Hawaii where the melon fly is very abundant, entire

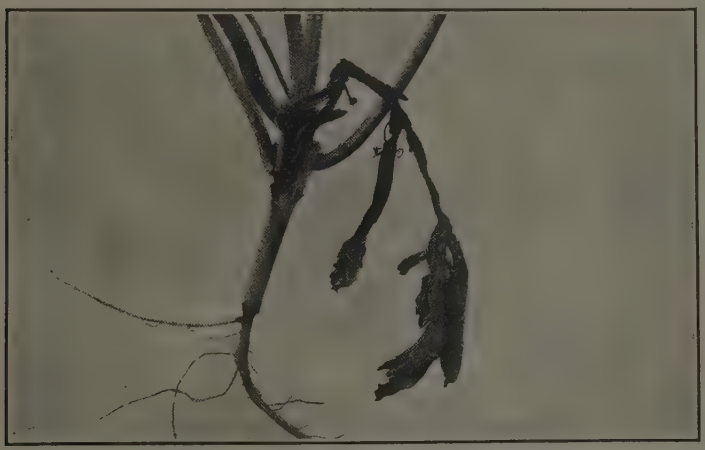

FIG. 8.—Seedling watermelon showing runner killed back by burrowing melon-fly larvæ. (Authors' illustration.)

fields of watermelons may be killed before the plants can develop runners. Squash, pumpkin, cucumber, tomato, and bean seedlings almost never are attacked. Larvæ never are found in the roots of older plants.

INJURY TO THE STEM.

As the plant becomes older, it is still subject to attack. The female fly lays her eggs in the rapidly growing pumpkin and squash vines, but the larvæ after hatching do very little damage, although they are able to mature. They often cause abnormal swellings or cancerlike spots where a colony of them are feeding, as illustrated by figure 7; but if the injury threatens the stem, the plant throws out roots on either side of the part affected to offset the damage. Such attacks upon the stem are not of importance, except in the case of watermelon and cantaloupe.

But in the two plants last mentioned the injury resulting from attack upon the stems may be very serious, and in many cases cause a complete failure of the crop. Figure 9 shows a portion of a canta-

FIG. 9.—Cantaloupe vine attacked by melon fly in eight places, including stalk, leaf petioles, and young fruit. (Authors' illustration.)

loupe vine that has been attacked in eight places. So persistent is attack upon cantaloupe in Hawaii that the vine can not be grown satisfactorily except in isolated spots or under cover.

Figures 1 and 10 show a common condition found in watermelon fields. The female fly usually chooses the growing tip of the runners in which to lay her eggs. In making a place in the vine for her eggs she practically severs the tip of the vine so that it may fail to grow

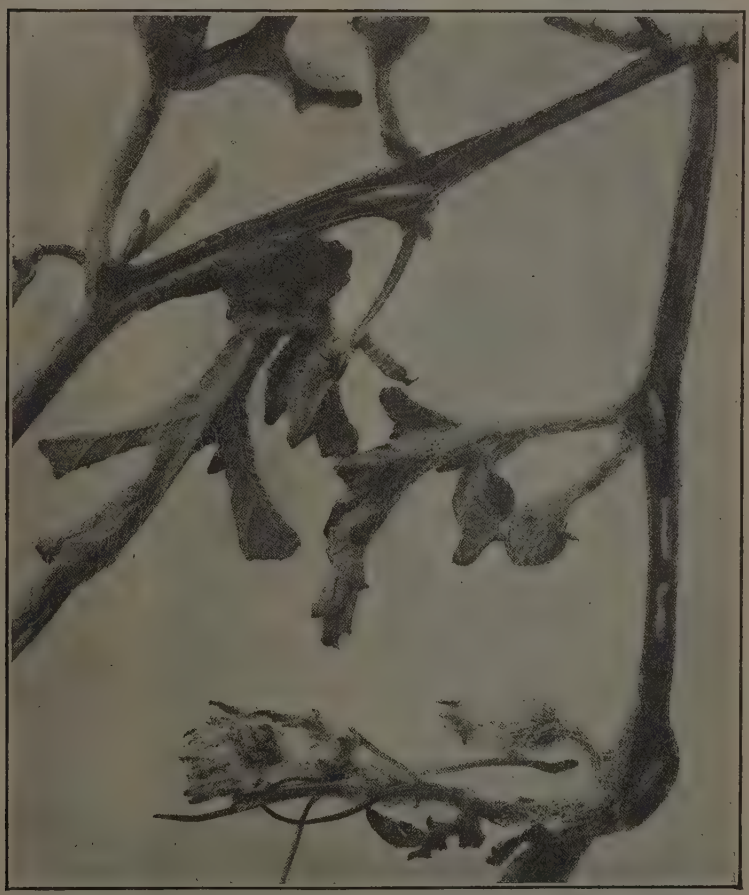

FIG. 10.—Succulent watermelon vine sectioned to expose five well-grown larvæ of the melon fly which have eaten out the interior, causing the vine to wither and die back to the point of original infestation. (Authors' illustration.)

beyond the point of injury. The growing end of the vine, however, usually is ruined, for, if the egg-laying process does not cause serious damage, the larvæ hatching, numbering from 2 to 10, begin to feed and bring about a hasty destruction. Figure 1 shows the drooping,

withered, growing tip. In this case the eggs were laid just beyond the leaf and flower stalks.

When the eggs are laid in the older though still very young and succulent watermelon vine, the larvæ, on hatching, tunnel their way

FIG. 11.—Melon-fly eggs in blooms of pumpkin. Two buds of the male bloom sectioned to show the eggs deposited through the corolla. (Authors' illustration.)

through the vine, eating out the center and causing it to wilt and die. Figure 10 shows a vine sectioned to expose the five well-grown larvæ which have killed it beyond the base of the leaf in the upper left-hand corner of the illustration. The serious setback to vine develop-

ment that this type of injury causes is readily apparent. Such pruning back of the vines, repeated over and again, may prevent the formation of sufficient growth for the development of fruits.

INJURY TO THE BLOOM.

Although injury to the seedling plant and to the growing stem is greatest in watermelon and cantaloupe and is of little importance among squashes, cucumbers, and pumpkins, the injury to the bloom is very serious among all these crops except that of the cucumber. Among pumpkins and squashes both the male and female blooms are affected; but among the watermelons, cantaloupes, chayotes, and Chinese marrows the male or staminate bloom escapes attack. It is not uncommon to examine luxuriantly growing fields of squashes and pumpkins during the warm months and not find a single unaffected bloom. Uninformed growers often question why their vines set no fruits. The condition of the blooms illustrated in figures 11 to 14 is the answer.

The unfertilized ovaries of all cucurbit blooms are especially attractive to female melon flies. The flies lay eggs in the undeveloped and unfertilized ovaries of the bloom before the blossom unfolds, and the larvæ, on hatching, often so ruin the ovaries, as indicated by their burrows shown in figure 12, that the flower never unfolds. In those varieties having long, narrow fruits the ovaries are many times so eaten out and decayed that the weight of the upper part of the bud causes the ovary to break (see fig. 13). So complete is the destruction

FIG. 12.—Work of melon-fly larvæ in bringing about destruction of ovaries of pumpkin bloom even before the corolla has entirely withered.

of the ovaries of watermelon bloom that in dry weather the remains of the bloom wither and become mummified, as shown in figure 15.

An examination of the buds of the male bloom in any field throughout the coastal regions of the Island of Oahu, particularly during the months from March to November, will reveal the severity of attack centered on this portion of the plant. Wherever the buds have been attacked, a whitish gumlike excretion exudes which hardens about the point of attack. On cutting the buds lengthwise, batches of eggs can be seen among the folds of the corolla, or in the stamens and receptacle, as shown in figure 11 (p. 12). As the eggs are pure white and are in clusters of 2 to 10 or more, they are seen easily without the aid of a lens. If the eggs have been laid from 2 to 6 days, the inside of the bud may have been already eaten out by the rapidly developing larvæ. Buds attacked before they are half grown usually are destroyed completely before the blossom unfolds. Figure 14 shows three stages in the destruction of the staminate bloom. The bud *a* is a mass of decay within; the stamens have been devoured and the larvæ already have begun to burrow about the base; *b* shows a bud that has been severed by the feeding of the larvæ and has fallen over under its own weight; and *c* is the upright stem of the bud, after the essential parts of the bloom have been ruined and have fallen to the ground. Although attack may occur so late in the development of the male bloom that the corolla can unfold, it is more often than not that eggs, or even young larvæ, can be seen on the inside of the corolla when the flower is in full bloom. The melon fly never attacks the bloom after the corolla has unfolded.

FIG. 13.—Pistillate bloom of squash in which larvæ of the melon fly have so devoured the unfertilized ovary that the bloom is destroyed before the flower can unfold. (Authors' illustration.)

INJURY TO NEWLY SET FRUITS.

The greatest destruction among fruits usually occurs when they are very young, either before they are fertilized or just after they have set. At this stage of development the young fruits are expanding very rapidly. Figure 16 shows the damage done to three young pumpkin fruits. About the damaged areas calluses are formed by the fruit in an attempt to repair the damage, but this attempt seldom

prevents secondary decays from starting, and these bring about the destruction of such portions as escape the larvæ. The sectioned pumpkin in figure 17 shows how a colony of larvæ may eat into a young fruit, become full grown, and leave it without causing a complete destruction. It also shows how smaller, weaker colonies may develop in the outer portion of the pulp.

INJURY TO OTHER FRUITS.

Complete destruction of fruits by larvæ of the melon fly rarely occurs after they have become 4 to 5 inches in diameter, for then

FIG. 14.—Buds of male flowers of pumpkin damaged by larvæ of melon fly, *a*, *b*, and *c* representing various stages in the destruction of the bloom. (Authors' illustration.)

the portion of the fruit containing the seeds, or the part preferred by the larvæ, is well protected by the outer meaty pulp and by the rind. Such colonies of larvæ as are then able to become established in pumpkins and squashes usually develop in the outer portions of the fruit and do not penetrate to the center. In cantaloupes, watermelons, cucumbers, and marrows, however, the larvæ more easily may work their way down to the softer, central portions and there complete their development, while the outer portion of the fruit remains quite firm. Figure 19 (p. 20) shows the cross section of a watermelon that had the general external appearance of being sound.

Yet, when cut open, it was found that its center had been eaten away entirely and the well-grown larvæ had made tunnels, shown somewhat reduced, throughout the rind.

Numerous similar examples of destruction might be described. But it is important to remember the fact that melon-fly attack upon the older fruits is far more likely, except in the case of the cantaloupe, cucumber, and tomato, to result in larval development in open surface wounds and in deformities.

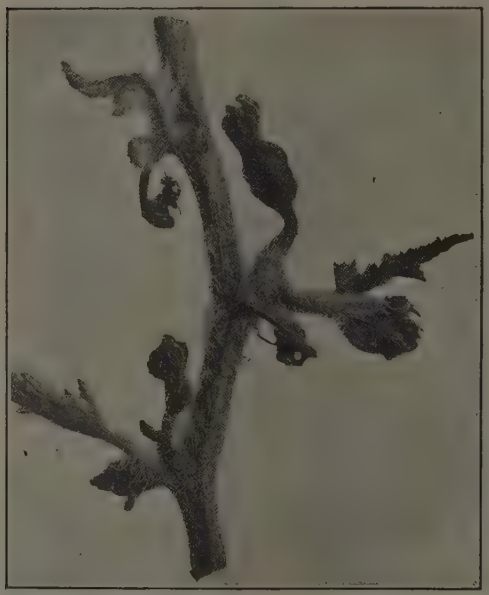

FIG. 15.—Section of watermelon vine, showing two fruits so devoured by larvæ of the melon fly that they have become mummified during dry weather following attack. Note that the remains of the blossom still persist. (Authors' illustration.)

One of the squashes of figure 21, the cucumbers of figure 18, and the watermelon of figure 20 illustrate types of deformities very common in Hawaii. Wherever the fruits have been only slightly damaged by melon-fly attack, deformities result. It is seldom that a perfectly formed cucurbit is seen in the markets of Honolulu unless the fruit was grown under protective coverings. Although deformities do not completely ruin the fruit, they restrict development and prevent the fruit from reaching its normal size, as illustrated by the unaffected squash and the badly deformed squash of figure 21 (p. 22). Cucumbers and watermelons so badly deformed as those shown in figures 18 and 20 are not salable, even though they contain no larvæ. The purchaser of fruit has learned from experience that deformed cucumbers must be viewed with suspicion, for, although they may be fit for the table, they may contain maggots.

FOOD OR HOST PLANTS.

The food or host plants of the melon fly may be divided into those preferred and those occasionally infested and may be listed as follows:

CULTIVATED.

Preferred.

1. Cantaloupe.
2. Watermelon.
3. Pumpkin.
4. Squash.
5. Gourds.
6. Chinese cucumber (*Momordica* sp.).
7. Chinese melon.
8. Chayote.
9. Cucumber.
10. Tomato.
11. String beans.
12. Cowpeas.

Occasionally infested.

1. Eggplant.
2. Water lemon (*Passiflora* sp.).
3. Orange.
4. Fig.
5. Papaya.
6. Peach.
7. Mango.
8. Citrullus (Java).

WILD.

1. *Sycos* sp.
2. *Momordica* sp.

Erroneously recorded host fruits.

1. Kohlrabi.
2. Cabbage.
3. Peppers.

CUCURBITACEOUS PLANTS.

All the cucurbitaceous plants are subject to severe infestation, particularly of the young fruits. Cantaloupes are the most susceptible, since the vines as well as the fruit are attacked badly at all stages of growth, and the fruits do not appear to develop the resistance to attack found among the older watermelons, pumpkins, and squashes. Ordinarily the cucumber is resistant to attack when very young, although it is rare that cucumbers offered for sale in Honolulu do not show some evidence of attack, even when very carefully collected. Cantaloupes and cucumbers may be used successfully by the female fly for egg laying up to the time

FIG. 16.—Various deformities of very young pumpkins caused by infestations started before or just after fertilization of the ovary. These fruits persist for a time, owing to calluses developing about points of attack, but they never reach a much larger size and are ultimately destroyed by fungi and secondary attack. (Authors' illustration.)

they are ready for market. Although cantaloupe growing has been abandoned practically in Hawaii since the advent of the melon fly, cucumbers are grown without protection of any sort. Practically all fruits reaching a size fit for salad use show evidences of attack at one or more spots, but the percentage of fruits rendered unmarketable is not large enough to force the oriental growers to cover the young fruits, although it would appear disastrously large to American market gardeners, who place a high value on their time. During midwinter 150 out of 153 cucumbers, ready for the market at Moiliili, were found infested variously.

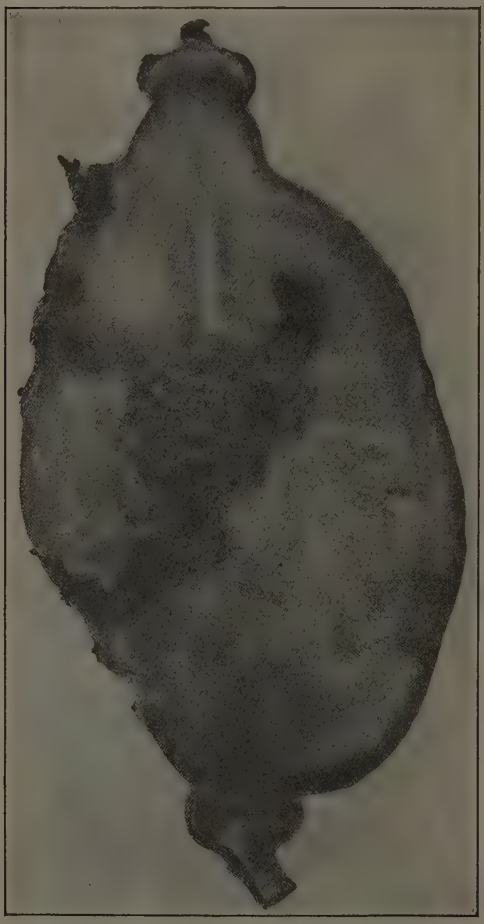

FIG. 17.—Cross section of young pumpkin, showing work of larvæ of melon fly. Each affected area represents the location of a colony of larvæ. (Authors' illustration.)

All cucurbits grow with such rapidity in Hawaii that the oriental is willing to permit the pest to destroy fully 50 per cent of the fruits rather than go to the expense of covering each fruit as soon as or before it sets. To prevent wholesale injury, all cucurbits except cucumbers must be covered before or just after blooming.

Aside from the fact that the seedlings and vines of all cucurbits except cantaloupe and watermelon are attacked but slightly, there is little difference in the susceptibility to attack of the young fruits under

Hawaiian conditions. Inasmuch as the fly has been permitted to increase unchecked since its introduction, it has become so abundant that slight differences in inherent resistance to attack are not evident

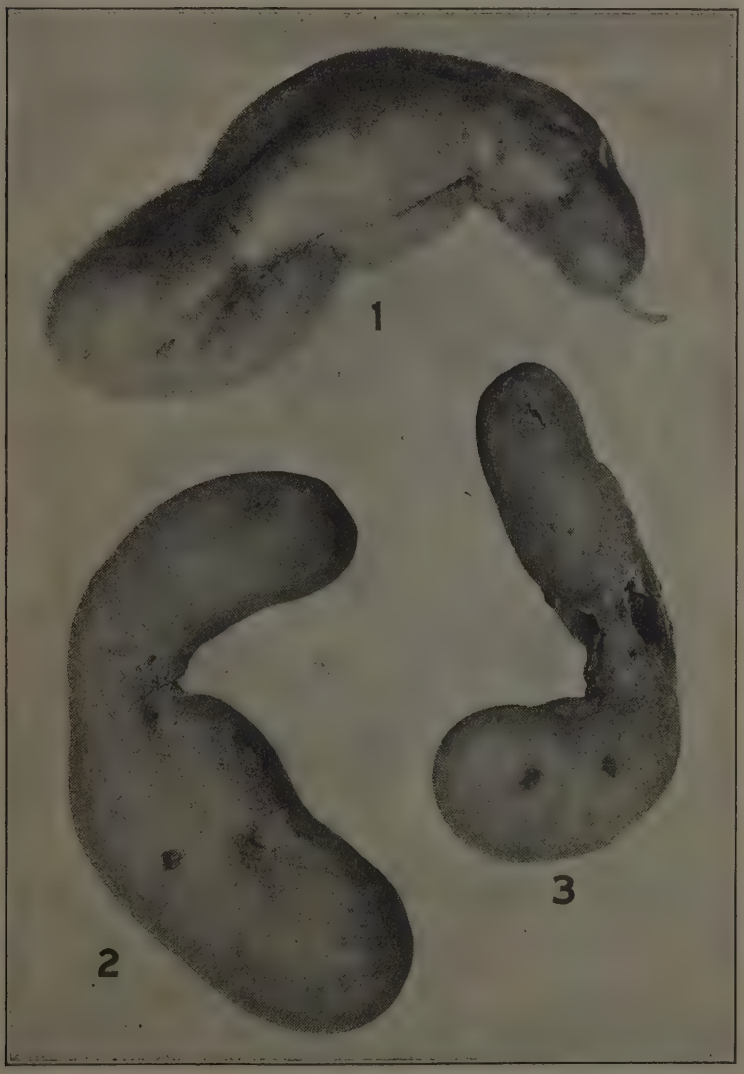

FIG. 18.—Damage to cucumbers by larvæ of melon fly. (Authors' illustration.)

among host fruits growing in the field. The infestation is excessive in all unprotected fruits. If by chance pumpkins, squashes, and watermelons escape infestation until they are from 4 to 6 inches

in diameter they may reach maturity, although before they reach maturity pumpkins and squashes may support numerous colonies of larvæ in open surface wounds and become badly deformed. Out of 254 nearly full-grown pumpkins growing at Kahuku during the winter months, 250 were found variously deformed. As many as 650 adults have been reared from a pumpkin not more than 4 inches long; the staminate bloom while still a bud may support as many as 37 well-grown larvæ.

TOMATOES.

Tomatoes are very susceptible to attack. All tomatoes offered for sale in Honolulu are likely to be infested, as shown by the reports of

FIG. 19.—Cross section of young watermelon, showing destruction of interior by larvæ of melon fly. Reduced one-fourth. (Authors' illustration.)

the market fruit-fly inspector covering several months. Fifteen ripe or partly ripe fruits examined at Hauula on March 21, 1915, contained eggs or larvæ. Such severe infestation is so general during the warmer months that data are superfluous. Under climatic conditions less favorable for the increase of the melon fly the tomato probably would be found to be less susceptible to attack than cucurbitaceous crops. The fruits of the small wild tomatoes and the spiny yellow-fruited Solanum, common in Hawaii, all are found growing about fields of cucurbitaceous crops, but never yet have been found infested. During January and February fields of tomatoes may produce a large percentage of sound fruits, owing to the effect of the

cooler weather upon the activities of the fly. Only the fruits of the tomato are subject to attack.

STRING BEANS.

The ordinary varieties of string beans grown on the mainland as a rule are not infested by the melon fly. Of the variety commonly known as the Yellow Wax bean, 375 pods sufficiently ripe to have turned color were examined at Haleiwa and were found free from attack, although growing close to a field of badly infested pumpkins, in March. Examinations of string beans in other localities, particularly about Honolulu, indicate that seldom are any of the varieties infested except the more fleshy, long-podded Chinese variety. This variety may be attacked very badly when grown near other favored host fruits or on land recently cleared of such crops, as illustrated by figure 22. As many as 36 well-grown larvæ have been found within a single pod.

FIG. 20.—Deformed watermelon resulting from late infestation by larvæ of melon fly. (Authors' illustration.)

Although the Chinese variety is the only one at times generally and badly affected, beans of all varieties except the Lima bean should be included in quarantine lists. The Lima bean never has been found infested. Only the pods of beans usually are infested. The larvæ prefer to feed upon the fleshy portions of the pod, but sometimes attack the seeds. In badly infested pods, attacked before the seeds are well grown, the larvæ may eat out the seeds and leave nothing but the outer portion untouched. This also is true of cowpeas.

COWPEAS.

Although cowpeas are not grown to any great extent in Hawaii, they are subject to melon-fly attack. Only the pods are affected. As many as 37 larvæ have been taken from a single pod. When infestation occurs early the young seeds may be devoured, but attack is centered more often upon the pod itself. Some varieties of cowpeas appear to be less liable than others to attack by the melon fly.

FRUITS AND VEGETABLES THAT ARE SELDOM OR NEVER ATTACKED.

Several observers have stated that the melon fly attacks eggplant, bell peppers, cabbage, and kohlrabi. During a period of three years the representatives of the department have not found any of these vegetables affected. The Mediterranean fruit fly has been found attacking eggplant and bell peppers, but only in small numbers. Even in the laboratory eggplant was found immune to melon-fly attack if the fruits were sound. Adult melon flies, however, were reared from fruits first weakened by decays.

FIG. 21.—Damage to squash by larvæ of melon fly. Of the two fruits illustrated, the one to the right is normal, and the one to the left, the stunted and deformed fruit caused by melon-fly attack. (Authors' illustration.)

Adults have been reared from orange, mango, fig, papaya, peach, apple, and water lemon. These fruits, however, do not serve regularly as hosts of the melon fly. Only in rare instances does the melon fly attack them, and then only slightly. For practical purposes aside from quarantines all the fruits and vegetables listed under this subheading are free from attack by the melon fly.

INTERESTING FACTS CONCERNING THE ADULT FLY.

The most interesting facts about the adult melon fly center about the length of life and the capacity to lay eggs. No flies have been

known to live longer than 4½ days without food and water, or longer than 5 days with water but no food. But if they can feed upon plant juices, such as the sap that exudes from cut or broken surfaces of pumpkin vines, cucumber fruits, papayas, etc., or the sap exuding from the breaks made in host plants during egg laying, adults may live many months. One female lived from February 17, 1914, to April 4, 1915, or 13½ months. The length of adult life is variable

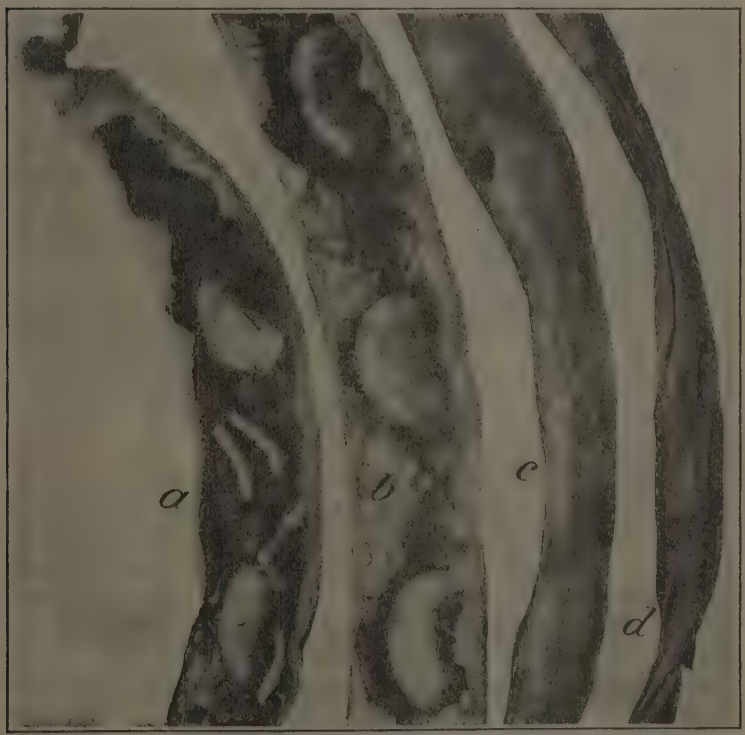

FIG. 22.—Destruction of green bean pods by larvæ of melon fly. In *a* and *b* a portion of the pods has been removed to expose larvæ and their work. In *a* are shown four well-grown larvæ. Pods in different stages of drying out after the larvæ have left them are shown in *c* and *d*. (Authors' illustration.)

under like conditions. From the standpoint of longevity the chief interest centers about the fact that certain adults may live long periods and thus keep the pest alive during seasons when host fruits are not in season.

Female flies may begin to lay eggs as soon as 14 days after they emerge from the pupa during the warmer months, when the mean temperatures range from 75° to 79° F. During the winter, at a mean

of about 71° F., many adults may not lay until 44 days after emergence. The season of the year and the nature of their food have an influence upon the rapidity with which eggs are formed.

But once the female fly begins to lay eggs, she may continue to do so throughout life. The largest number of eggs laid by any female in confinement is 687, but 1,000 probably may be laid by vigorous long-lived flies. While 37 is the largest number of eggs laid by a single individual during any one day, the number varies, and may be as few as 1. On many days no eggs are laid. Unlike the female of the Mediterranean fruit fly, which lays a few eggs almost daily, the female melon fly lays more eggs per day, but at greater intervals. Thus one fly deposited 14, 19, 13, 29, 16, 19, 16, 12, 17, 7, 9, 16, 7, 12, 37, 25, 24, 21, 28, 6, and 18 eggs, respectively, per day during the first three months (summer months) after depositing her first eggs; she laid no eggs in fruits until she was 51 days old, and, after she began laying, laid eggs on only 21 out of 90 days. During the seventh, eighth, and ninth months of her life (winter months) she deposited 10, 2, 18, 14, 15, 20, 13, 9, and 3 eggs.

Female flies can resume normal egg laying after periods of scarcity of host fruits. Females that have not been given an opportunity to lay eggs within fruits for periods ranging from 3 to 9 months after emergence have begun to deposit eggs at a normal rate as soon as fruits were placed with them in the laboratory rearing cages.

WHY THE MELON FLY IS A SERIOUS PEST.

The melon fly is a serious pest in Hawaii because it finds in the coastal areas a favorable climate and plenty of food. Regardless of the great discouragement due to its ravages, the oriental market gardeners, and others to a less extent, plant its host vegetation in rotation on the same or neighboring plats of ground. No attempt is made to prevent the flies from maturing in infested fruits. The decaying and infested fruits of the cucumber crop, for instance, are left on the field that is to be planted to tomatoes, or the flies developing from the cucumbers migrate to attack the melons just coming into bearing in the near-by field. No system of control, aside from covering successfully a small portion of the fruit that sets, is practiced.

It thus happens that large numbers of adults mature, and, as the climate is favorable, they multiply rapidly. During the warmest Hawaiian weather, when the mean temperature averages about 79° F., the egg, larva, and pupa stages may be passed in as few as 12 or as many as 29 days, according to the individual and its host. The complete life cycle is subject to great variation, according to the

longevity of the adult. Since one female fly has been known to live 431 days, it is evident that the complete life cycle from the laying of the egg to the death of the fly may be 443 to 460 days when the immature stages are passed during the warmer portions of the year. At an average mean temperature of about 68° F., which is the coolest temperature found in Hawaii where fruits are available in numbers for study, the immature stages are passed in 40 to 45 days. It is difficult to state just what the variation in the life cycle may be in colder climates, but it may range between 3 and 4 months.

This rapidity of increase throughout the coastal regions permits from 8 to 11 generations of the melon fly a year, when a generation is considered to extend from the time the egg is laid until the female of the next generation begins to deposit eggs. As the females are capable of living many months and of depositing eggs at frequent intervals throughout life, the generations become hopelessly mixed. It is possible for a female ovipositing on January 1 to be still alive and laying eggs the following January along with the progeny of 11 generations of her descendants. It is, therefore, small wonder that the melon fly, under such favorable conditions, swarms throughout the market gardens of Hawaii and leaves little unaffected that is not protected by man.

CONTROL MEASURES.

NATURAL CONTROL.

No agencies at present are working in the Hawaiian Islands to bring about, even periodically, a very large natural reduction in the abundance of melon flies. The mortality among the immature stages, or among the adults, is not sufficiently high to be of practical value, although sometimes 90 per cent of the larvæ may be found dead in certain decaying fruits.

In climates colder than that of the Hawaiian coastal areas mortality due to cold temperatures will play a particularly active part in reducing the pest. While the cooler weather of the winter months does prolong the period of development throughout the coastal regions, the long life of the adult flies and the capacity of females for continued egg-laying make it difficult for market gardeners to benefit to any marked extent from the effects of cool weather if they allow their fruits to remain unprotected. The cooler weather in the more isolated gardens holds down the number of adults and limits their activity to a fewer hours during the day when it is warm enough for them to attack fruits, and in this way makes possible greater success in saving fruits by the use of various protective coverings than follows the use of the same measures during the summer months.

PARASITES.

Hawaii has no native parasites that attack the melon fly, but the Hawaiian Board of Agriculture and Forestry has introduced a parasite from India. This parasite [1] was introduced at Honolulu during the early part of 1916, and has been reared and distributed in large numbers, but it is not known yet whether it will check the ravages of the melon fly in a practical manner. It has become established, however, and promises to be useful.

ARTIFICIAL CONTROL.

Individual growers of vegetables in Hawaii are likely to be discouraged in the application of remedial measures for the control of the melon fly. Host fruits are grown in rotation in the numerous garden spots and market-garden areas chiefly by uneducated orientals, who do not appreciate the necessity for a united fight against the fly. The usual custom among these laborers is to permit infested fruits to decay in the field. In certain uncultivated areas the wild Sycos and Chinese cucumbers run wild and furnish fruits in which the melon fly can breed throughout the year, even though no cultivated crops are grown. This abundance of cultivated and wild host fruits, coupled with a climate favorable for rapid multiplication, produces many adult flies which spread in all directions to render valueless all remedial measures except those that involve protective coverings for the fruits.

It thus happens that no artificial control measures have been applied successfully in controlling the melon fly under Hawaiian conditions. The only means now employed to safeguard fruits is that of protecting the young fruits with some type of covering until they are large enough to withstand attack. Trapping adults has proved a failure, and killing them by spraying thus far has given poor results. If all growers would cooperate systematically (1) in the destruction of the eggs and larvæ by submerging infested fruits in water or by boiling and (2) in the destruction of the adults by spraying, the value of spraying with a poisoned bait and of covering the young fruits would be enhanced to a point where either might be sufficiently effective to be recommended as satisfactory. But so long as the cultivation of host plants is largely in the hands of orientals and others who do not appear to be amenable to instruction as modified by western standards, no relief can be expected.

SPRAYING.

Since adult melon flies do not deposit eggs for 2 to 4 weeks after emergence during the summer, and only after relatively longer periods

[1] *Opius fletcheri* Silv.

during the winter, but feed continuously throughout this period, it is evident that any spray that will kill them before they begin to lay eggs is valuable. A poisoned-bait spray, containing 5 ounces of lead arsenate in paste form, 2½ pounds of brown sugar, and 5 gallons of water, is very effective in killing adults. This spray, used at the rate of 30 gallons to the acre, was applied by means of a knapsack sprayer. About 2 acres of Chinese melons and cucumbers in a field fairly well isolated, from the Hawaiian standpoint, which means that no host fruits were growing within 500 yards, were sprayed on May 21, 26, and 28, June 1, 4, 8, 14, and 23 during typical summer weather. Six hours after an application many adults were sluggish and flew with difficulty, but within 24 hours many dead adults could be found among the vines. Although the adults were lessened numerically by the spray, the young fruits were punctured as badly at the end of the experiment as at the beginning.

Although negative results have followed the use of poisoned-bait sprays in Hawaii, failure has been due to the peculiar conditions surrounding the fields sprayed that permit an influx of female flies. Under commercial conditions, where cantaloupes, pumpkins, and watermelons are grown in large quantities in fairly dry climates, it is reasonable to believe that sufficiently good results will follow the use of poisoned sprays to make their application practicable as a method of control.

DESTRUCTION OF INFESTED FRUITS.

Larvæ and eggs may be killed by submerging the infested portions of the plant in water, or by burying, boiling, or burning. Choice of method will depend largely upon the amount of fruit to be handled and upon local conditions. There is no surer way to kill all immature stages than to boil or burn the fruits. Burning is often expensive, and, when trash in compost holes is depended upon to furnish the fuel, is likely to be unsatisfactory, particularly where, as in Honolulu, the quantity of infested material is so great. Bringing infested fruits to the boiling point will kill all forms. The submerging of fruits in ordinary tap water for five days will either kill all larvæ and eggs or stop further development.

Burial in soil is a satisfactory method, provided the fruits are buried deep enough and cracks are prevented from developing in the earth above the fruits as the latter decay and settle. It must be remembered that just after transforming from the pupa the adults are so soft that they can force their way through very small openings. A crack in the soil extending down to the fruit, even though it be no wider than ordinary blotting paper, is still wide enough to allow the adults to reach the surface and thwart the purpose of fruit burial. Adults can not make their way through a foot

of well-tamped soil, but have been known to force their way through 2 to 3 feet of dry loose sand beneath which their pupæ had been buried.

Because burial and burning may be left to subordinates who may not have the interests of the owner so much at heart, boiling or submergence in water is more highly recommended. The larvæ will not injure cattle if the fruits are used as feed, but many larvæ may escape before they are eaten; hence this method of destruction is not recommended unless the fruits have a real value as a food.

PROTECTIVE COVERINGS.

The protection of fruits and plants by covering with soil, paper, or cloth is a great labor-consuming operation, yet this is the only method that will protect under present Hawaiian conditions. Even

FIG. 23.—Protecting cucurbits from attack by melon flies. Each fruit (in this case of *Momordica* sp.) is placed, immediately after it has been fertilized, within a long envelope made of newspaper. (Authors' illustration.)

as practiced to-day, less than 25 per cent of all fruits covered, except certain Chinese marrows, are actually saved from attack. In a slightly cooler climate than that of coastal Hawaii a high percentage of the fruits could be saved. As it is, the great attraction of the unfertilized ovaries of the bloom makes it difficult to put on coverings before the flowers are infested. During the warmer portions of the year the bloom of cucurbits, with the exception of the cucumber, should be protected at least three to four days before the flower unfolds. At present many fruits are covered, but rather indifferently and ineffectively. During April only 9 out of 43 fruits of the Chinese melon that had been covered were sound, while on the same date 119

out of 692 young protected watermelons were actually free from infestation.

Certain Japanese growers ward off attack by burying the young fruits in the soil or by surrounding them with straw or trash until they are sufficiently old to withstand fatal attack. In certain light soils cantaloupes are kept buried in the soil until they are ripe and they appear upon the market almost white in color. The most successful of protective coverings are those shown in figure 24. In this case the Momordica vines are grown over bushes, hence the young fruits can be found easily and inclosed in long cases made from newspapers and resembling envelopes cut across at both ends. These cases are left open at the lower end, but are never entered by the adult flies.

MEASURES TAKEN TO KEEP THE FRUIT FLIES OF HAWAII FROM GAINING A FOOTHOLD IN CONTINENTAL UNITED STATES.

The Federal Horticultural Board, by means of its Quarantine No. 13, entitled "Mediterranean Fruit Fly and Melon Fly," issued March 23, 1914, is doing all that man can do to prevent the two fruit-fly pests of Hawaii from becoming introduced into mainland United States. The regulations of the quarantine practically have put a stop to the movement of fruits and vegetables from Hawaii. Certain fruits and vegetables, however, such as bananas of the noncooking type, pineapples, taro, and coconuts, and others, when it can be shown to the satisfaction of the Department of Agriculture that in the form in which they are to be shipped they are not and can not be a means of conveying either the Mediterranean fruit fly or the melon fly, may be moved or allowed to move from Hawaii into or through any other State, Territory, or District of the United States when they have been inspected by the United States Department of Agriculture, certified to be free from infestatation, and marked in compliance with the regulations. Pineapples, taro, and coconuts do not support the fruit flies of Hawaii, neither do bananas when shipped according to trade requirements. In practice the quarantine eliminates all shipments of fruit except the four just mentioned, and of these pineapples and bananas only are regularly shipped.

The enforcement of the quarantine is divided between the representative of the board in Hawaii and those at the ports of entry to the mainland, notably San Francisco, San Pedro, and Seattle. In Hawaii it is the duty of the inspector to see that the fruit is grown under conditions reasonably sanitary from a fruit-fly standpoint, that each package or bundle offered for shipment is inspected and bears a certificate to that effect, and that transporting companies do not re-

ceive for shipment consignments of fruit unless they have received from the Federal Horticultural Board a permit for such action. These permits, which give data on the kind, amount, and origin of fruit, the name and address of consignor and consignee, and dates, are issued in triplicate; the duplicate and triplicate remain in the files of the transporting company and the Federal Horticultural Board, respectively. The original is attached to the bill of lading accompanying the shipment and no consignment of fruit is permitted to leave the ship at the port of destination unless this permit is presented to the Federal inspector.

The duty of the inspector at the mainland ports is to make certain that no express or freight consignments leave ships arriving from Hawaii unaccompanied by the permit above mentioned, and that no quarantined fruits or vegetables are present either in the ship's lockers as ships' stores or in the possession of passengers, for all such are contraband after the ship passes within the 3-mile limit of the mainland. The inspector of the port of entry also must receive from each passenger a statement that he has in his baggage no contraband fruits or vegetables. Inspectors also have the right to search the personal belongings of passengers and members of the crew.

There seems little danger of fruit-fly pests reaching the mainland from Hawaii in commercial consignments of fruit since Quarantine No. 13 went into effect. *The greatest danger at present lies in the careless introduction of the pests by uninformed travelers who, without appreciating the great financial losses the Government is attempting to avert, persist in concealing about their persons and baggage contraband fruits, or in sending these by express or post in packages the contents of which are not stated truthfully.* These are the avenues of introduction that no law can close thoroughly. To close them, honesty and cooperation with the Federal Horticultural Board on the part of all are necessary.

SUMMARY.

The melon fly, a native of the Indo-Malayan region, is one of a number of very destructive pests that are likely to be introduced into the mainland United States. The quarantine officers of the Federal Horticultural Board and of California are each year intercepting it in infested fruits at California ports on ships from the Hawaiian Islands.

The melon fly was introduced into Hawaii about 1895 by Japanese immigrants in fruits which they brought with them as food from Japan. Before its arrival in Hawaii, cantaloupes, watermelons, tomatoes, and all kinds of cucurbitaceous crops, such as pumpkins, squashes, cucumbers, etc., were grown in large quantities and were

cheap. They could be grown in every dooryard. Because of the ravages of the pest, these crops can not be grown now by the average person, and only with great difficulty in market gardens. Many fruits must be imported, and the cost of all has been increased as a result of melon-fly attack. Even cowpeas and string beans may be infested. It is impossible to overstate the destructiveness of the melon fly to cucurbitaceous crops under Hawaiian coastal conditions, where none of these can be brought to maturity except with the exercise of the greatest care on the part of market gardeners.

Since there are as many as 8 to 11 generations of the melon fly a year, and the female flies may live to be over a year old and lay eggs throughout life, the pest can multiply very rapidly. No agencies have been found to be working at present in Hawaii that bring about, even periodically, a great natural reduction in the abundance of melon flies. No native parasites are known to attack the melon fly, but it is hoped that the parasite introduced from India during 1916 may prove effective. In colder climates cold weather will prove a marked and valuable control factor. Predacious enemies and several forms of mortality recorded are of no practical value under Hawaiian conditions.

No satisfactory artificial measures have been applied successfully in combating the melon fly under Hawaiian conditions. Poisoned-bait sprays promise to yield effective results under other cultural conditions. In Hawaii these sprays would be effective if they were used consistently and universally, but they are not. At present cucurbits can be grown only by the use of coverings of various sorts for the protection of the very young fruit. Killing the immature stages by submergence in water, by burial in soil, or by boiling are not applied as methods of control, although they are effective when intelligently applied. Artificial methods of control are not likely to prove satisfactory in Hawaii so long as the growing of the chief host plants remains in the hands of uneducated oriental laborers who do not practice clean cultural methods or cooperate in applying remedial measures.

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